

Appendix D

Overview of Site-Specific Selenium Threshold Development for Brown Trout

Introduction and Background

Selenium is one of the primary ecological chemicals of potential concern (ECOPCs) for the Smoky Canyon Mine Site-Specific Ecological Risk Assessment (SSERA). It is also a chemical that is undergoing extensive revision of the national surface water quality criterion. The process for revision of the water quality criterion includes evaluating data on potential toxicity of selenium to sensitive aquatic organisms. To date, the literature has indicated fish are one of the most sensitive organisms due to effects found in young developing fry that may cause deformities significant enough to affect survival. Those effects best correlate to tissue concentrations in egg or ovaries.

In 2015, the U.S. Environmental Protection Agency (USEPA) released its most current Draft National Criterion (USEPA 2015). The criterion includes a proposed tissue based value for selenium using maternal transfer studies where adult fish were exposed and passed on selenium to developing eggs. A number of studies have been conducted on several different species providing a range of effects for different species. Effects data for one sensitive species, brown trout, is included in the 2015 Draft National Criterion and the study is based on J.R. Simplot Company (Simplot) work at the Smoky Canyon Mine site.

To support application for a site-specific selenium standard for Sage Creek and Crow Creek downstream of the Smoky Canyon Mine, studies on developmental toxicity for brown trout were conducted using trout and trout eggs collected from the Site. Results of this study are an important element of the new toxicity data being considered for the 2015 Draft National Criterion (USEPA 2015). Trout adult reproduction studies (described below) conducted by Simplot have received extensive peer review and scrutiny. These studies conducted using wild trout from the Smoky Canyon Mine Site are particularly relevant for establishing site-specific thresholds for selenium in fish tissue and thus are relevant for use in the Smoky Canyon SSERA. The site-specific studies have been the subject of intensive peer review.

This appendix provides background information for reviewers to understand how the site-specific tissue threshold for selenium was developed for the SSERA, and includes the following:

1. Timeline and process;
2. Development of the exposure concentration (EC_{10}) to be used;
3. Translating the egg tissue based value to a whole body tissue value;
4. Translating these values to aqueous values;
5. How Simplot's development process for a site-specific threshold value for selenium in fish tissue compares to the 2015 Draft National Criterion process; and
6. Implications of certain aspects of the 2015 Draft National Criterion on the Smoky Canyon Mine SSERA.

Chronology

Simplot began work in 2006 studying the effects of selenium on the aquatic environment near the Smoky Canyon Mine. This work also included extensive trout population studies on local streams, and included three primary components:

- Literature review;
- Field collection of environmental data from the watershed and other areas; and
- Laboratory reproduction studies with wild and hatchery trout species, brown trout and Yellowstone cutthroat trout.

The site-specific selenium criterion (SSSC) Work Group spearheaded by the Idaho Department of Environmental Quality (IDEQ) (and including representatives from USEPA headquarters, USEPA Region 10, Idaho Fish and Game [IDFG], U.S. Forest Service [USFS], and Wyoming Department of Environmental Quality [WDEQ]) provided valuable input into the planning and development of the field and laboratory studies. In August 2010, a draft document was submitted to the SSSC Work Group, titled *Draft Interpretive Findings for Field and Laboratory Studies and Literature Review in Support of a Site-Specific Selenium Criterion* (Interpretive Report) (NewFields 2010) for review and solicitation of comments. Comments received were integrated into the Draft Interpretive Report to revise the document and develop it into a formal proposal to IDEQ for a site-specific selenium criterion.

In March of 2011, the SSSC Work Group was informed by USEPA Region 10 that the USFWS was going to provide comments on Simplot's Draft Interpretive Report (August 2010; NewFields 2010). Involvement of the USFWS came at the direction of the United States Senate Committee on Environment and Public Works chaired by Senator Barbara Boxer. In March 2011, Senator Boxer sent a letter to Mr. Rowan Gould, Acting Director of USFWS, and to Ms. Lisa Jackson, Administrator of the USEPA. In the letter to Director Gould, Senator Boxer requested that scientists at the USFWS review the described document and provide "technical assistance" to the Committee on Environment and Public Works. In the letter to Administrator Jackson, Senator Boxer requested that USEPA "consider, and where relevant, integrate federal assistance from federal scientists from outside of the agency." The letter then stated that the Committee on the Environment and Public Works would forward this information to USEPA.

In January 2012, Simplot submitted its *Proposed SSSC and a Technical Support Document (TSD)* (Formation 2012) to the SSSC Work Group. The TSD was the revised version of the Interpretive Report and incorporated the comments received from the SSSC Work Group. The EC₁₀ proposed, based on survival for brown trout fry, was 20.8 milligrams per kilogram dry weight (mg/kg dw).

Within one day of the submittal, the USFWS, through Senator Boxer's office, submitted its technical review of the Draft Interpretive Report (i.e., the precursor to the TSD) to the USEPA and published its review on the USFWS website. The USFWS review was conducted by Dr.

Joe Skorupa (USFWS 2012) and provided a number of comments and conclusions on the Draft Interpretive Report with a large amount of emphasis on the Brown Trout Adult Reproduction studies (Formation 2011). This review and comment document was conducted on the earlier Draft Interpretive Report and not on the more recent submittal of the Proposal and TSD. Nonetheless, the USFWS review brought up some questions about the Brown Trout Study and the endpoints derived that needed to be addressed.

Prior to and during this time, USEPA was developing a Revised National Criterion for Selenium based on fish tissue residues in egg/ovaries, and USEPA had expressed its intent to utilize the Brown Trout Study data. Due to some of the questions raised by Dr. Skorupa from USFWS, USEPA contracted the Eastern Research Group (ERG) to conduct a peer review of the analyses that utilized the Brown Trout Study data in the context of questions raised by USFWS. The result of this effort was the "*External Peer Review of the Interpretation of Results of a Study on the Effect of Selenium on the Health of Brown Trout Offspring*" (ERG 2012). In this document, six experts were charged with addressing five specific questions related to the Brown Trout Study and Dr. Skorupa's review.

In April 2013, Simplot submitted responses to the USFWS comments to the SSSC Work Group and USEPA. Included within the comment responses were two attachments:

- Attachment 1 - *Data Quality Assurance Report: Reproductive Success Study with Brown Trout (Salmo trutta)* (AECOM 2012).
- Attachment 2 - Count of Normal Fish and Total Number of Fish for Each Sample from the Deformity Assessment.

These additional data were included in the responses to comments to provide additional information to USEPA and other reviewers who were using the Brown Trout Study data to derive EC₁₀s from that study for survival and deformities. USEPA had provided to Simplot its preliminary analyses of the Brown Trout Study data and it was clear some of the analyses conducted were based on assumptions being made about the data where no assumptions were needed. The attachments provided the necessary data to eliminate some of USEPA's assumptions.

Following submittal of the comment responses and attachments, USEPA altered some of its analyses to make use of the additional data. Again, following the development of those analyses, USEPA contracted for a Peer Review of pertinent questions regarding the revised analyses of the brown trout data. The result of that effort was the document titled "*External Peer Reviewer Comments on Review of Draft USEPA Report, Analysis of the Brown Trout Selenium Toxicity Study Presented by Formation Environmental and Reviewed By U.S. Fish And Wildlife Service (June 2014)*" (GLEC 2014). Similar to the previous peer review, six experts were charged with addressing five specific questions posed by USEPA about the analyses conducted.

In May 2014, USEPA released its *External Peer Review Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater (2014)*. The resulting egg/ovary criterion presented was based on the 5th percentile of the different species sensitivity distribution (n = 14 EC₁₀ genus mean chronic values), with the most sensitive species being brown trout. Within the 2014 Draft National Criterion document, USEPA cited a range of egg/ovary thresholds derived from the brown trout data that ranged from 15.91 to 21.16 mg/kg dw egg selenium. This range was based on three different endpoints (survival, deformities, and a combined endpoint of survival and deformities). Simplot, along with a number of other agencies, private firms, and individuals, provided comments on USEPA's Draft document in July 2014. The ERG was subsequently contracted to conduct a peer review of the 2014 Draft National Criterion. Seven reviewers provided their expert opinions on questions posed by USEPA and ERG regarding the 2014 Draft National Criterion, the results for which are compiled in the *External Peer Review of the Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater 2014* (ERG 2014).

In July 2015, USEPA released a revised Draft National Criterion for selenium, and again presented an alternative threshold value for brown trout. In the 2015 Draft National Criterion, USEPA elected to use only the survival endpoint which resulted in a value of 18.09 mg/kg dw egg selenium. White sturgeon was also included in the 2015 Draft National Criterion which proved to be the most sensitive species. With the derivation of the survival endpoint, the brown trout threshold for survival (only using the hatch to swim-up data) resulted in it being the third most sensitive species behind sturgeon and bluegill sunfish.

The above chronology documents the extent of interest and peer review generated for Simplot's Brown Trout Study. As one of the more sensitive species studies where reproductive effects were examined, inclusion of this study and the range of potential analysis outcomes in the overall 2015 Draft National Criterion have been heavily vetted.

Currently, USEPA's 2015 Draft National Criterion for selenium provides the most current and easily accessible compendium of reviews, different interpretations, and various effects thresholds derived using Simplot's Brown Trout Study data. Furthermore, it provides summary information for all the other studies utilized in the derivation of the 2015 Draft National Criterion. However, while the USEPA 2015 Draft Criterion is cited as a convenient document housing the data and providing background on the various analyses conducted for this study, the 2014 and 2015 Draft National Criterion values are not being used to assess potential risks for Simplot's Smoky Canyon Mine SSERA.

Defining the Best EC₁₀ to Use as a Site-Specific Risk Threshold

In their review of the available literature at the time, Janz¹ et al. (2010) noted in *Selenium Toxicity to Aquatic Organisms* that for the eight species presented, the thresholds for

¹ Dr. Janz ultimately became one of the peer reviewers, not only of Simplot's brown trout studies, but also of the 2014 Draft National Criterion.

reproductive effects fall into a narrow band of 17 to 24 mg/kg dw in eggs. GLEC (2014) indicated the USEPA calculated brown trout EC_{10} of 16.76 mg/kg was used in a Species Sensitivity Distribution for derivation of a national criterion even though USEPA recognizes that more than 90 percent of the various EC_{10} values it calculated (including those for the comprehensive endpoint “combined survival and deformities”) fall above its recommended EC_{10} of 16.76 mg/kg for brown trout. In deriving the 2015 Draft National Criterion, USEPA is not contending that 16.76 mg/kg is the only scientifically appropriate EC_{10} that can be obtained from this study data.

Indeed, in Formation’s TSD (2012) a survival EC_{10} of 20.8 mg/kg dw was submitted as its proposed site-specific criterion value based on the brown trout data. USEPA (2014) suggested a value of 15.91 mg/kg dw even though the range of possibilities from the analyses of the brown trout study data were as high as 21.16 mg/kg dw. For this range USEPA used survival, deformities, and a combined/integrated endpoint for surviving fish that are fully normal.

In their comments on the USEPA’s 2014 Draft National Criterion, Simplot agreed that a combined endpoint for surviving normal fish was a strong endpoint. A combined endpoint seems logical and smooths out some of the data spread introduced from the deformity data (i.e., proportion fully normal). However, use of a less conservative endpoint for the proportion of normal fish eliminates the noise within the deformity data and allows for a more accurate fit of the model to the data. Using USEPA’s approach to derive a combined endpoint, Simplot derived an endpoint for surviving fish with insignificant deformities (i.e., 0 and 1 rankings). The EC_{10} for this approach is 20.5 (LCL = 19.81, UCL=21.24) mg/kg dw egg selenium². The EC_{10} for surviving fish with insignificant deformities is only slightly lower than the worst-case scenario for the combined endpoint. Given the relatively insignificant difference between 20.5 mg/kg egg selenium (insignificant deformities), 21.16 mg/kg egg selenium (optimistic scenario), and 20.65 mg/kg egg selenium (worst-case scenario), a combined endpoint that reduces uncertainty by eliminating the subtle differences between no deformities and slight deformities (which are not expected to cause effects on survival, growth, or reproduction) is a logical choice.

The dose response curves, whether they be for survival, deformities, or a combined endpoint, allow for the derivation of a fairly narrow range of EC_{10} thresholds. Formation’s TSD (2012) noted that prior to any dose response modeling, effects for several of the endpoints seemed apparent between 20 and 25 mg/kg dw and ultimately proposed an EC_{10} of 20.8 mg/kg dw for survival. Using a combined endpoint, Formation suggested an EC_{10} of 20.5 mg/kg dw in its comments to USEPA on their 2014 Draft National Criterion. USEPA’s numerous analyses of this data set have defined a range of 15.91 to 21.16 mg/kg dw egg selenium.

Given all of these analyses, for the Smoky Canyon Mine SSERA Simplot believes it is appropriate to use a range of values based on the evidence available. USEPA’s most recent

² This EC_{10} was derived using a Tolerance Distribution and a triangular data distribution with fitted data for the Logx50 of 1.34 and Y0 of 0.87 using the Toxicity Relationship Analysis Program (TRAP), version 1.21A (Erickson 2012). An earlier version was also used: TRAP version 1.2 (Erickson 2008).

survival EC₁₀ of 18.09 mg/kg dw certainly falls within the viable range as does Formation's combined surviving and normal endpoint value of 20.5 mg/kg dw egg selenium. Risks to aquatic receptors from selenium will be evaluated based on this range of EC₁₀ values for selenium in egg tissues.

Translating from Egg to Whole Body Tissue Concentrations

For most sites, whole body or muscle tissue is the type of fish tissue data available. Relating the effects threshold for selenium to its concentration in egg/ovary tissue can pose a problem, in that the effects threshold data will not be comparable to the available field data. Recognizing this limitation, most of the studies conducted for adult reproduction where selenium was measured in egg or ovary tissues also measured selenium in whole body and/or muscle tissues. Ratios of the egg to whole body tissue concentrations could then be derived to "translate" an egg/ovary effect threshold to a whole body tissue concentration. Bioaccumulated selenium in adult female fish is either stored or transferred into eggs prior to oviposition. Trout undergo vitellogenesis for a period of months prior to depositing eggs. As noted previously for vitellogenesis, Janz et al. (2010) state that "As a result, for salmonids, the dietary intake of selenium immediately prior to spawning may not have a major impact on egg selenium concentrations. Instead, selenium from tissue storage sites, including the liver and muscle, will likely contribute proportionally more selenium to the oocytes in this fish." These internal tissue storage sites contribute to the whole body tissue selenium concentrations.

Although the ultimate sources of selenium to the maternal adult are diet and ambient water, selenium must be absorbed by the adult and transferred to the oocytes. Therefore, there is a causal relationship between selenium in the adult tissue and the eggs.

This statistical relationship between egg and whole body tissue selenium can be developed either through regression analysis or through simple ratios. Because of the simplicity by which egg to whole body tissue ratios can be developed as compared to generating a regression analysis, and using the equation to predict a whole body tissue concentration from an egg value, the ratio approach is commonly used.

For brown trout, the site-specific egg to whole body translation factor is 1.45. This value is used to convert egg/ovary tissue concentrations to whole body tissue equivalent values by dividing the egg tissue value by the translation factor. The whole body equivalents for brown trout using the range of egg effect tissue concentrations noted above (e.g., 18.09 and 20.5 mg Se/kg (dw egg)) are 12.48 and 14.14 mg/kg dw selenium. These values will be used as tissue thresholds to compare to measured trout tissue concentration data from the various locations sampled for the Smoky Canyon Mine SSERA. Because at this time there is no information that suggests sculpins are more sensitive to selenium effects than are trout, sculpin tissue data are also compared to the trout tissue thresholds.

Defining an Aqueous Value from an Egg Effect Threshold

Appendix K of 2015 Draft National Criterion (USEPA 2015) provides a concise summary of the trophic model used to derive an aqueous concentration from an egg effect threshold and trophic transfer function data collected from the Site.

Below, the equation for derivation of an aqueous value based on effects in eggs is presented.

$$C_{water} = \frac{C_{egg-ovary}}{EF \times TTF_{composite} \times CF}$$

where:

C_{water} = dissolved aqueous concentration of selenium (milligrams per liter [mg/L])

$C_{egg-ovary}$ = target egg selenium threshold for brown trout (mg/kg dw)

EF = selenium concentration (mg/kg dw) in particulate materials / dissolved selenium concentration in water [$C_{particulate}$ (periphyton, detritus, sediments) / C_{water}] (L/kg dw)

$TTF_{composite}$ = product of the trophic transfer function values of the fish species that is the target for the egg-ovary threshold

CF = species specific proportion of selenium in eggs relative to the concentrations of selenium in whole body tissues (CF = 1.45)

Based on the information presented above, the target egg threshold is a range of EC₁₀ values from 18.09 to 20.5 mg/kg dw. To derive the aqueous selenium concentration using the above equation, several different input variables are necessary including concentrations of selenium in periphyton/algae and/or sediments, benthic invertebrate tissues, and fish tissues at different trophic levels to comprise the $TTF_{composite}$ and EF variables. These data can be collected across different time periods and locations, and thus integrated in a number of different configurations, all of which affect the resulting derived aqueous concentration. Derivation of the EF produces the most uncertainty in the calculation because it serves as the initial bioaccumulation factor integrating selenium into the food chain. In addition, a variety of different approaches exist to integrate seasonal data collected from a range of different locations and exposure conditions. Careful consideration of logical food web linkages, critical exposure periods, and exposure locations must be made in order to derive a representative aqueous value. Diets used for the various TTFs derived were based on logical and reported information about species dietary preferences. To eliminate the seasonal differences, the fall data were used to focus on periods when brown trout are forming eggs and being exposed to selenium concentrations that may

ultimately affect maternal transfer of selenium to developing embryos. While some intermittent brief spikes of high selenium concentrations occur, typically as high flow commences (e.g., ascending limb of hydrograph), selenium concentrations are typically diluted during high flows. Sustained, longer duration exposure to elevated selenium occurs during the low flow periods. Locations evaluated also affect how data are integrated, in that data from both background and downstream areas were available. Because data from the downstream areas have selenium concentrations that are elevated due to source inputs, the data integration process focused on areas downstream of source inputs for deriving aqueous concentrations downstream of source inputs. Locations downstream of source inputs that were included in the derivation of the aqueous concentrations included: HS-3 (Hoopes Spring), LSV-2C and LSV-3 (Sage Creek), LSS (Lower South Sage), CC-1A and CC-3A (Crow Creek downstream of Sage Creek).

Consistency with the Process

Section 5 of the 2015 Draft National Criterion briefly describes a process for derivation of a site-specific criterion, and points to Appendix K (USEPA 2015) for compiling and using the various trophic data that would be used in deriving a water-based value from a tissue based number. The concept pointed out in this brief discussion is the following statement, “The most relevant testing would measure the survival and occurrence of deformities in offspring of wild-caught female fish to determine an EC₁₀ for selenium in the eggs or ovaries (e.g., following Janz and Muscatello 2008).” The Simplot studies did exactly that for two important management species. Further, the site-specific studies compiled all the necessary trophic data to model egg effects thresholds to water concentrations as shown previously.

References

AECOM. 2012. Reproductive success study with brown trout (*Salmo trutta*). Data quality assurance report. Final. December.

ERG (Eastern Research Group, Inc.) 2012. External Peer Review of the Interpretation of Results of a Study on the Effect of Selenium on the Health of Brown Trout Offspring. EPA Office of Science and Technology. Contract No. EP-C-12-021.

ERG (Eastern Research Group, Inc.). 2014. External Peer Review of the Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater 2014. EPA Office of Science and Technology. Contract No. EP-C-12-021.

Erickson, R.J. 2008. Toxicity Relationship Analysis Program (TRAP) Version 1.2. U.S. Environmental Protection Agency, Washington, D.C. 2008.

Erickson, R.J. 2012. Toxicity Relationship Analysis Program (TRAP) Version 1.21A. U.S. Environmental Protection Agency, Washington, D.C. 2012.

Formation Environmental (Formation). 2011. Brown Trout Laboratory Reproduction Studies Conducted in Support of Development of a Site-Specific Selenium Criterion. Prepared for J.R. Simplot Company by Formation Environmental. Revised October 2011.

Formation Environmental (Formation). 2012. Technical Support Document: Proposed Site-Specific Selenium Criterion, Sage and Crow Creeks, Idaho.

Great Lakes Environmental Center (GLEC). 2014. External Peer Reviewer Comments on Review of Draft EPA Report, 'Analysis of the Brown Trout Selenium Toxicity Study Presented by Formation Environmental and Reviewed by U.S. Fish and Wildlife Service'. Prepared for the USEPA Office of Water, Washington, D.C.

Janz, D.M., D.K DeForest, M.L. Brooks, P.M. Chapman, G. Gilron, D.Hoff, W.A. Hopkins, D.O. McIntyre, C.A. Mebane, V.P. Palace, J.P. Skorupa, and M. Wayland. 2010. Selenium Toxicity to Aquatic Organisms. In P.M Chapman, W.J. Adams, M.L. Brooks, C.G. Delos, S.N. Luoma, W.A Maher, H.M. Ohlendorf, T.S. Presser and D.P. Shaw (eds). 2010. Ecological Assessment of Selenium in the Aquatic Environment. SETAC Press, Pensacola, FL, USA.

Janz, D.M. and J.R. Muscatello. 2008. Standard operating procedure for evaluating selenium-induced deformities in early life stage fish. In: Selenium tissue thresholds: tissue selection criteria, threshold development endpoints, and potential to predict population or community effects in the field. Washington, D.C.. North American Metals Council – Selenium Working Group. www.namc.org. USEPA. 2014. External Peer Review Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater 2014. Washington, D.C., EPA 822-p-14-001.

NewFields. 2010. Draft Interpretive Findings for Field and Laboratory Studies and Literature Review in Support of a Site-Specific Selenium Criterion, Smoky Canyon Mine. Prepared for J.R. Simplot Company by NewFields and HabiTech. August.

U.S. Environmental Protection Agency (USEPA). 2014. External Peer Review Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater 2014. Washington, D.C., EPA 822-p-14-001.

U.S. Environmental Protection Agency (USEPA). 2015. Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater 2015. Washington, D.C., EPA 822-p-15-001.

U.S. Fish and Wildlife Service (USFWS). 2012. Technical Review: Smoky Canyon Mine Site-Specific Selenium Criterion Report. U.S. Department of the Interior, Fish and Wildlife Service, Division of Environmental Quality, Environmental Contaminants Program.